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DESIGN AND MANUFACTURING OF A POSITIVE CLAMP FOR AUTO POUR STOPPER ROD MACHINE- A CASE STUDY

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ABSTRACT

The main aim of this paper under study is to overcome drawbacks of the present clamping system used to clamp the locking plate of an auto pour stopper rod machine. Auto pour stopper rod machine is used to pour molten metal into the moulds to produce various components by casting. Locking plate is a component of the machine which is bolted to the actuator arm. It is necessary to clamp the locking plate firmly to prevent leakage of molten metal.

The present system which is used to clamp the locking plate is a pneumatic brake caliper which makes use of compressed air to apply clamping force. The functioning of this brake stops when power supply is cut off, thus releasing the locking plate that leads to leakage of molten metal. The temperature of molten metal is around 1400^{0}C and hence its leakage can cause fatal accidents. This study emphasizes a new system which makes use of spring force to clamp the locking plate. The new system does not require electricity to clamp the locking plate thus preventing leakage of molten metal in case of power failure.

KEYWORDS: Clamping, Locking Plate, Molten Metal, Pneumatic Brake, Spring

INTRODUCTION

AUTO POUR STOPPER ROD MACHINE

An auto pour stopper rod machine is used for pouring molten metal at 1400^{0}C in the moulds to produce various components by casting. Axles, transmission parts, engine parts and brake parts are a few examples of parts manufactured by this method.

The various parts of this machine are

1) Actuator arm 5) Twist Cylinder

2) Stopper Rod 6) Locking plate

3) Bail 7) Brake

4) Bail Clamp 8) Nozzle

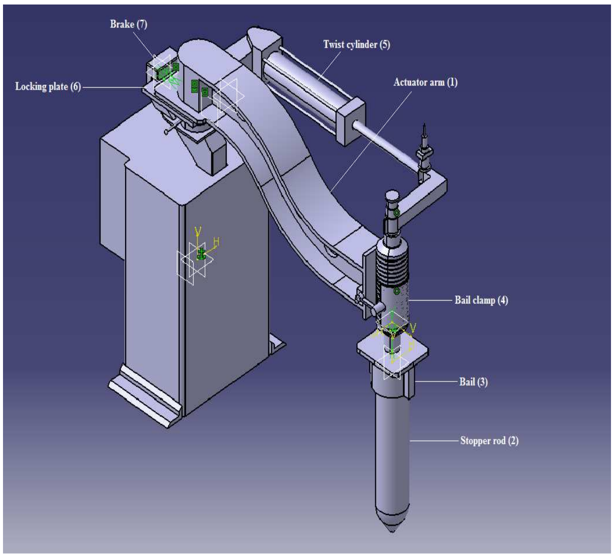

Figure 1: CATIA Drawing of Auto Pour Machine

WORKING

The combined unit consisting of the bail and graphite rod along with the threaded portion is called as the stopper rod (2). As shown in Figure 1, bail (3) is used to hold the graphite rod and bail clamp (4) is used to hold the threaded portion of the stopper rod.

The currently used system relates to a stopper rod positioning and control apparatus which is used to control the flow of molten metal from a reservoir through a bottom pour nozzle.

The lift apparatus is mounted centrally on a vertically oriented longitudinal axis. The lift apparatus has an inner tube telescopically mounted within an outer tube. This inner tube has reciprocating motion along the longitudinal axis. A servomotor is mounted at the bottom of the outer tube. The servomotor output is interconnected to the inner tube whereby actuation of the servomotor results in reciprocating motion of the inner tube.

One end of the actuator arm is bolted to the locking plate and the other end is connected to the stopper rod. As mentioned above, the flow of molten metal through the nozzle is controlled by positioning of the stopper rod. The stopper rod (2) must be positioned and held firmly to prevent leakage of molten metal out of the reservoir. Effective clamping of the locking plate (6) is necessary for proper positioning of the stopper rod (2) to prevent the leakage.

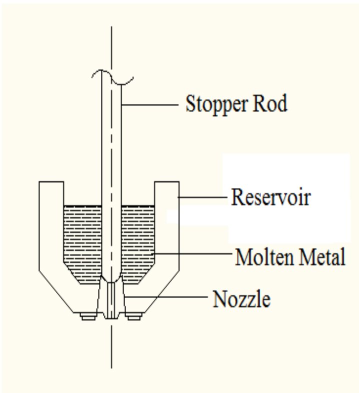

Figure 2: CAD Drawing of Stopper Rod Positioning

PRESENT SYSTEM: PNEUMATIC BRAKE CALIPER

The locking plate is clamped by means of a brake caliper. The brake used is similar to the disk brake used in automobiles. The locking plate is clamped in between the two calipers. Each caliper has two friction surfaces which come in contact with the plate. This is a pneumatically operated brake which is used to clamp the locking plate when compressed air is supplied at a desired pressure (say 5 bar). Compressed air is supplied from a central compressed system which is used for a variety of applications in the factory.

The pneumatic brake has the following specification:

- **Maximum Pressure Rating:** 5 bar
- **Housing Material:** Die Cast Aluminium
- **Seals:** Buna- N Standard
- **Bolts**: Zinc plated Grade 8
- **Friction Material:** Replaceable, high grade
- **Piston (Friction Pads) Diameter:** 41.3 mm

LIMITATIONS OF PRESENT SYSTEM

- The main limitation of 'pneumatic brake caliper' is that in case of power failure, the brake stops functioning.
- Due to use of compressed air for a variety of applications, sometimes there is a possibility of pressure drop. Even a small amount of fluctuation in the pressure and air leakage affects the working of the brake.
- Due to leakage of molten metal, production process is hampered.

Taking into consideration these above mentioned drawbacks, we have developed a new system for clamping the locking plate.

POSITIVE CLAMPING SYSTEM

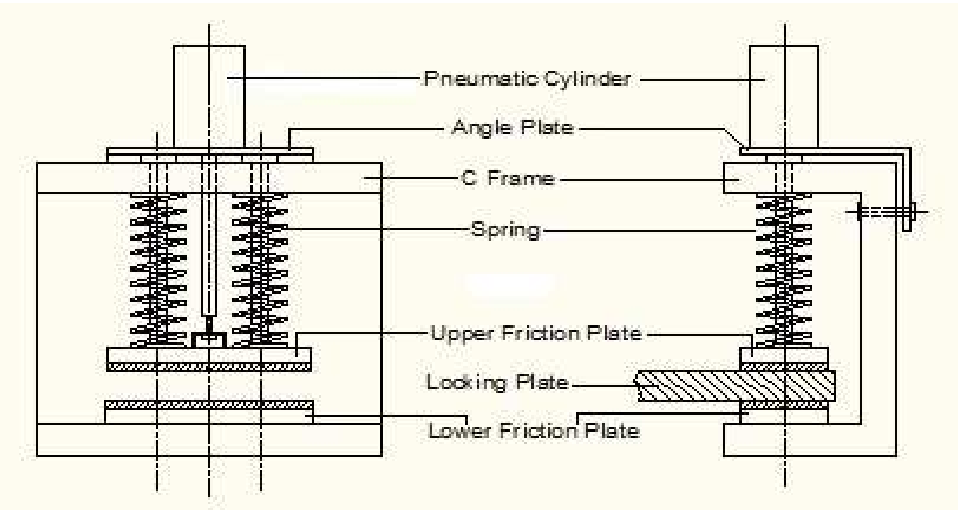

Figure 3: CAD Drawing of Positive Clamping System

CONSTRUCTION

The new clamping system makes use of spring force for locking the plate. The entire system consists of two helical compression springs, two friction plates and a pneumatic cylinder mounted on the angle plate as shown in Figure 3. The rod of the pneumatic cylinder is connected to the upper friction plate. The lower friction plate is bolted to the C-Frame. The springs are preloaded in such a way that the distance between the friction plates is kept less than the thickness of the locking plate. This ensures effective clamping of the locking plate. Guides are provided to prevent buckling of the springs. The friction plates are in contact with the locking plate and clamp the plate firmly.

WORKING

The locking plate is clamped in between the friction plates by using spring force. The preloading of the springs exerts force on the locking plate as they try to regain their free length. The pneumatic cylinder is used to lift the upper friction plate against the spring force to release the locking plate. The rod of the pneumatic cylinder in the fully extended position is in contact with the upper friction plate as shown in Figure 3. When compressed air at a desired pressure (earlier used for pneumatic brake caliper) is supplied to the pneumatic cylinder, the rod retracts causing the springs to compress which lifts the upper friction plate by a small distance thus releasing the locking plate. When the supply of compressed air is cut off, the springs regain their initial position, thus clamping the locking plate between the friction plates.

This system has the following advantages over the present system:

- Electricity is required only to release the locking plate while it is clamped without supply of electricity.
- This system provides consistent clamping force.
- Easy maintenance of the system.
- Production process is not affected.

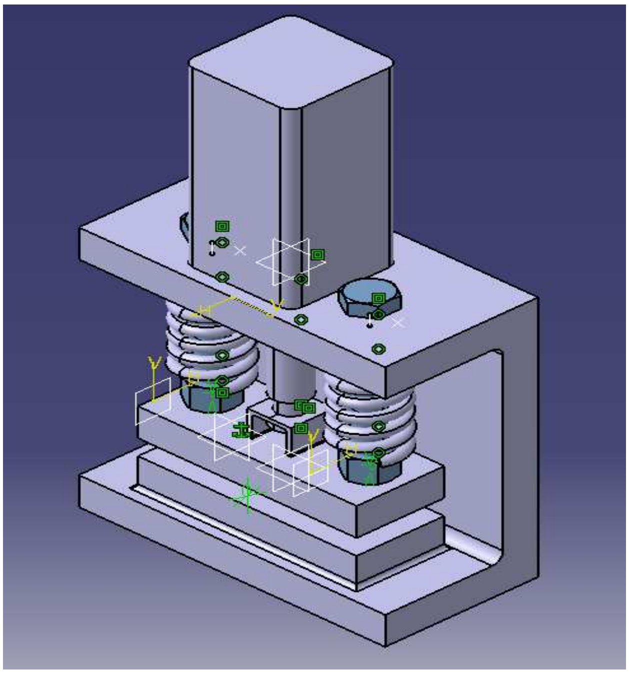

Figure 4: CATIA Drawing of Positive Clamping System

DESIGN

Present System: Pneumatic Brake Caliper

Known Parameters

- Diameter of friction pads of the brake caliper = 41.3 mm
- No of friction pads on each caliper = 2
- Assuming that compressed air is supplied to the brake at a pressure = 5 bar = 0.5 N/mm

Clamping force exerted on the locking plate is given by

F_b = Pressure x Area of friction pad x No of friction pads on each caliper

$= 0.5 \times \pi/4 \times d^2 \times 2$ .... (Friction pads are circular is shape)

$= 0.5 \times \pi/4 \times (41.3)^2 \times 2$

$$F_b = 1339.64\ \text{N} \tag{1}$$

The clamping force exerted by the brake on the locking plate is F_b = 1339.64 N.

Positive Clamping System

- **Design of Spring**

Known Parameters

- Wire Diameter d = 5 mm
- Ultimate tensile strength S_{ut} = 1190 N/mm^2
- Shear stress = 0.5 S_{ut} = 595 N/mm^2
- Modulus of rigidity G = 81370 N/ mm^2

Assuming spring index (C) as 4, mean coil diameter (D) is calculated as

$D = C \times d = 4 \times 5 = 20$

D = 20 mm

The spring force is assumed to be 10% more than the clamping force which is

$F_s = 1.1 \times 1339.64 = 1470$ N

Considering two springs in parallel combination, the force on each spring is given by,

$F = F_s / 2 = 1470 / 2 = 735$ N

Recoil deflection of spring is given by, $\delta = \dfrac{8 \times F \times D^3 \times N}{G \times d^4}$

Where 'N' is the number of active coils which are calculated as

$$N = \frac{\delta \times G \times d^4}{8 \times F \times D^3}$$

The upper friction plate is lifted by 5 mm, hence we consider $\delta = 5$ mm

$$N = \frac{5 \times 81370 \times 5^4}{8 \times 735 \times 20^3}$$

$= 5.40 \approx 6$

$N = 6$ (2)

Total number of coils is given by $N_t = N + 2 = 6 + 2 = 8$

$N_t = 8$ coils

Solid length which is the fully compressed length of the spring is given by

$N_t \times d = 8 \times 5 = 40$ mm

Actual deflection is given by,

$$\delta_{actual} = \frac{8 \times F \times D^3 \times N}{G \times d^4}$$

$$= \frac{8 \times 735 \times 20^3 \times 6}{81370 \times 5^4}$$

$\delta_{actual} = 5.54$ mm

Total axial gap is assumed to be 15% of the actual deflection which is given by

$0.15 \times 5.54 = 0.8324$ mm

The free length is given by

L_f = solid length + total axial gap + actual deflection

$= 40 + 0.8324 + 5.54$

$= 46.37 \approx 50$ mm

$L_f = 50$ mm (3)

The pitch of coil is given by, pitch = $\frac{\text{free length}}{\text{Total no. of coils} - 1}$

$$= \frac{50}{8 - 1}$$

Pitch p = 7.14 mm

Spring stiffness is given by $k = \frac{Gd^4}{8D^3N} = \frac{81370 \times 5^4}{8 \times 20^3 \times 6}$

$k = 132.43$ N/mm

- **Design of Cylinder**

Force $F_s = 1470$ N,

Pressure = 0.5 N/mm^2

Pressure = Force/ Area = $\frac{F_s}{\pi/4\,(d_p^2 - d_R^2)}$

Where d_p= piston diameter

d_R = Rod diameter

The clamping area is given by A = Force/ Pressure = 1470/0.5 = 2940 mm^2

$2940 = \pi/4\,(d_p^2 - d_R^2)$

$d_p^2 - d_R^2 = 3743.324$ mm^2

Taking standard value of rod diameter $d_R = 14$ mm,

$d_p^2 = 3743.324 + 14^2$

$d_p^2 = 3939.324$,

Hence $d_p = 62.76$ mm ≈ 63 mm

Hence we select a cylinder of standard bore diameter equal to 63 mm.

CONCLUSIONS

- This study explains the working of an auto pour stopper rod machine and the limitations of the present system of the machine.
- It explains the need to develop a better clamping system for effective and safe operation of the machine.
- The newly developed clamping system overcomes the drawbacks of the current pneumatic brake caliper system.
- Ease of manufacturing and maintainability provides added advantages over the existing system.

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